

THE PREVALENCE OF VISIBLE AND/OR OCCULT BLOOD ON ANESTHESIA
AND MONITORING EQUIPMENT

Captain Susan Marie Perry

APPROVED:

| | |
|---|------|
| W. Patrick Monaghan, SBB, CLS, Ph.D., Chair | Date |
|---|------|

| | |
|---|------|
| Maura S. McAuliffe, CRNA, Ph.D., Member | Date |
|---|------|

| | |
|------------------------------|------|
| Eugene Levine, Ph.D., Member | Date |
|------------------------------|------|

| | |
|--|------|
| Virginia K. Saba, Ed.D., RN, FAAN, FACMI, Member | Date |
|--|------|

Approved:

| | |
|--|------|
| F. G. Abdellah, Ed. D., Sc. D., RN, FAAN, Dean | Date |
|--|------|

DISCLAIMER STATEMENT

“This work was supported by the Uniformed Services University of the Health Sciences Protocol No. TO6143-01. The opinions or assertions contained herein are the private opinions of the author and are not to be construed as official or reflecting the views of the Department of Defense or the Uniformed Services University of the Health Sciences.

COPYRIGHT STATEMENT

The author hereby certifies that the use of any copyrighted material in the thesis entitled:

**“THE PREVALENCE OF VISIBLE AND/ OR OCCULT BLOOD ON ANESTHESIA
AND MONITORING EQUIPMENT”**

beyond brief excerpts is with the permission of the copyright owner, and will save and hold harmless the Uniformed Services University of the Health Sciences from any damage which may arise from such copyright violations.

ABSTRACT

This study examined the prevalence of visible and or occult blood on 6 types of equipment. This equipment included blood pressure cuffs, electrocardiograph cables, pulse oximeter probes, ventilator control switches, vaporizer control knobs and flow meter knobs. This equipment was inspected for visible blood and then tested for occult blood utilizing a three stage phenolphthalein test. A total of 28 operating suites from 2 separate medical facilities were used for data collection. The total sample size was 342 observations of the 6 types of equipment. Of the 342 observations, 32% were positive for occult blood. Only 6 samples were positive for visible blood. The presence of blood on this equipment may be in direct violation of the Occupational Safety and Health Administrations Blood-borne Pathogen Standard and the infection control guidelines of the American Association of Nurse Anesthetists and the American Society of Anesthesiologist. The presence of blood on this equipment may increase the risk for nosocomial and occupational exposure to viral and bacterial pathogens. Recommendations were made to decrease the risks from this contamination by redesigning equipment, increasing the use of disposable equipment and ensuring compliance with effective infection control procedures.

Key Words: Occult Blood, Contamination, Anesthesia Equipment, Blood, Anesthesia, Decontamination

THE PREVALENCE OF VISIBLE AND/ OR OCCULT BLOOD ON ANESTHESIA
AND MONITORING EQUIPMENT

by

CAPTAIN SUSAN MARIE PERRY, R.N., B.S.N.

THESIS

Presented to the Graduate School of Nursing Faculty of
the Uniformed Services University of the Health Sciences

in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF SCIENCE DEGREE

UNIFORMED SERVICES UNIVERSITY OF THE HEALTH SCIENCES

October, 1998

FORWARD

During the years 1992 to 1996 I worked as the Infection Control Officer for the United States Air Force Academy in Colorado Springs. Each month I would compile a list of hospital acquired infections for the previous month. Without fail most of the names on the list would be surgical patients. I conducted an informal study to look for common factors among the patients on the list and determined that there were several factors which consistently appeared.

I found that these were surgical patients, having operative procedures lasting two hours or more, who were undergoing general endotracheal anesthesia during their procedures. Also it was noted that the older patients, were likely to contract a nosocomial infection.

Having completed this inquiry, I tried to identify sources of nosocomial infection in the operating room. I was not successful in determining a cause. I did, however, note that while the operating room was cleaned after each case, there were a number of items which were not cleaned, or disinfected, between patients. These items were most often the machines and monitoring equipment used by the anesthesia staff. The interest for this study has grown from that observation. While this study will not prove a causal

relationship between the presence of blood and infections, it will investigate the presence of potential contamination on equipment used by anesthetists and will offer some recommendations for reducing the risk of infection to patients and staff.

DEDICATION

To Lillie, who from the first memory I have has served as my role model and hero. You gave me courage, inspiration, and a belief in myself and others. Because of you I know that the true meaning and happiness we find in life is through giving of ourselves to those who need us. You taught me to be understanding to those in need and strong when I encountered difficulties in my own life. I know you are still watching and I love you.

ACKNOWLEDGMENT

The assistance, guidance and support of numerous people have contributed to making possible the attainment of this degree. I am especially grateful to Dr. Patrick Monaghan, chairperson, and the members of the thesis advisory committee, Dr. Maura McAuliffe, Dr. Eugene Levine, and Dr. Virginia Saba. Their guidance, knowledge, and support was invaluable.

Grateful appreciation and much love is also extended to my husband, Anthony, who served as advisor, editor, and head cheerleader! You encouraged me every step of the way. Thank you for always believing we could “DO IT!”

Finally, I thank William, Jennifer, and Elizabeth for believing in this dream from the beginning and loving me through it all.

TABLE OF CONTENTS

| | |
|--|----|
| CHAPTER I: INTRODUCTION..... | 1 |
| Background..... | 1 |
| Rationale and Significance of the Problem..... | 2 |
| Purpose of the Study..... | 5 |
| Research Questions..... | 6 |
| Conceptual Model and Framework..... | 6 |
| Definitions..... | 9 |
| Assumptions and Limitations..... | 12 |
| CHAPTER II: REVIEW OF THE LITERATURE..... | 14 |
| Summary..... | 20 |
| CHAPTER III: METHODS..... | 21 |
| Research Design and Procedures..... | 21 |

| | |
|--------------------------------------|----|
| Measurement..... | |
| 22 | |
| Protection of Human Rights..... | 23 |
| Data Analysis..... | 23 |
| CHAPTER IV: ANALYSIS..... | 25 |
| Results..... | |
| 25 | |
| CHAPTER V: SUMMARY..... | |
| 29 | |
| Conclusions and Recommendations..... | 29 |
| REFERENCES..... | 37 |

LIST OF TABLES

| | |
|--|----|
| Table 1. Prevalence of Blood on Anesthesia Equipment and Monitoring Equipment Facility#1..... | 26 |
| Table 2. Prevalence of Blood on Anesthesia Equipment and Monitoring Equipment Facility#2..... | 27 |
| Table 3. Prevalence of Blood on Anesthesia Equipment and Monitoring Equipment Both Facilities and by Machine Type..... | 27 |

LISTS OF FIGURES

| | |
|---|----|
| Figure 1. Percentage Positive for Heme by Sampling Time/ Both Facilities..... | 28 |
| Figure 2. Percentage of Equipment Positive by Facility | 28 |

CHAPTER I: INTRODUCTION

Background

The problem of cross-infection has been around since there have been two of the same species and at least one pathogen. From as early as 1859 medical experts have been entreating their colleagues, as well as their patients, to employ asepsis to guard against the spread of disease (Nightingale, 1859; Buffum, et. al., 1926). With the advent of the Human Immunodeficiency Virus epidemic, there has been renewed interest in and emphasis on preventing the spread of blood-borne pathogens.

This new interest spawned updated regulations from the Centers for Disease Control (CDC), American Practitioners of Infection Control (APIC), Occupational Safety and Health Administration (OSHA), the American Society of Anesthesiologist, and the American Association of Nurse Anesthetists (AANA). These policies and regulations include procedures for cleaning and disinfecting anesthesia equipment. However, regulations are only effective if they are routinely employed by those tasked with complying with them. Properly cleaning and disinfecting anesthesia equipment protects both the patient and the provider (American Practitioners of Infection Control (APIC), 1996; Dorsch, 1983; Centers for Disease Control (CDC), 1996; Occupations Safety and Health Administration (OSHA), 1992). Therefore, the consistent cleaning and decontamination of anesthesia equipment by anesthesia staff should be routinely assessed for compliance.

Rationale and Significance of the Problem

In following the recommended procedures for cleaning and disinfecting anesthesia equipment, there are two benefits to be realized. First, there is the prevention of nosocomial infections. A nosocomial infection is defined as an infection that was not present or incubating when the patient was admitted to the hospital. Each year an estimated 6% of patients hospitalized in the United States will develop at least one nosocomial infection. The annual cost of nosocomial infections is estimated to be between \$5 million and \$10 million (Tait & Tuttle, 1995). Recent studies place the mortality related to nosocomial infections between 70,000 and 300,000 deaths annually (Martone, Jarvis, Culver & Haley, 1992).

In 1994 the Association of Operating Room Nurses (AORN) stated that “ the creation and maintenance of an aseptic environment has a direct effect on patient’s outcome (p. 109).” Although there are some cases which demonstrate a direct causality between anesthesia equipment and patient infection, causality is usually difficult to demonstrate. A direct relationship between anesthesia practice and nosocomial infections is easily obscured by the number of variables to which each patient is exposed during a surgical procedure (Tait & Tuttle, 1995).

Although a direct relationship may be difficult to prove, the number of procedures during which anesthesia personnel breach the protective barriers of patients, easily demonstrate the great potential for spread of infection. The intubation of the airway,

placement of the patient on a ventilator, arterial and venous cannulation, as well as cannulation of the spinal and epidural spaces, are but a few examples of overt invasive procedures performed by anesthesia staff.

Surgical patients are three times more likely than medical patients to suffer a nosocomial infection (Martone, et al., 1993). This is true even though they make up only 42% of the patient population. The most prevalent means of spreading infection is through direct transfer from one patient to the next by the hands of the health care provider. Surgical patients are generally not in the operating room at the same time. However, contaminated anesthesia equipment, not disinfected between surgical cases, may become the reservoir for the pathogen. When the anesthetist touches the surface of the equipment, they may then become the transmitter of nosocomial infections.

The second benefit to be gained by cleaning and disinfecting anesthesia equipment is to protect the anesthetist and staff. In 1991, 5,100 health care workers were infected with the hepatitis B virus as a direct result of an occupational exposure to blood. Ten percent of these workers will become chronic carriers, and of this group 107 will die as a result of their disease (Short & Bell, 1993). Serosurveys taken in the 1970s and 1980s showed a prevalence for HBV infection to be 13% to 49% among anesthesiologists. The HBV conversion rate for surgeons was 10% to 28% and that of the general population was 3%-14%. This indicates that the risk to anesthesia providers is higher than that of the general public and places them in the high risk category.

Although anesthesia staff generally take precautions when they know a patient is infected with a particular virus or disease, many may not take precautions with patients

not known to be infected with these diseases (O'Donnell & Asbury, 1992b). According to OSHA and CDC, health care workers must assume that there is the potential for all patients to be infected with a blood-borne pathogen. This is the basis for universal precautions and governs the way contaminated equipment must be disinfected. Due to the lag time between the contracting HIV and HBV, and the onset of symptoms, the patient may be contagious and not even aware of their disease status. Therefore, reducing the exposure to all blood or body fluids is the only reliable means of effectively reducing the risk of contracting a blood-borne disease (Telford & Quebbeman, 1993).

Anesthesia staff are not only exposed to blood, they are at risk for breaks in their skin barrier as well. Many of the procedures performed by anesthesiologists may cause cuts or abrasions to the skin, particularly of the hands. These procedures include frequent washing of hands, opening of glass ampules, and percutaneous needlesticks (Browne & Chernesky, 1988). During surgery and other invasive procedures, anesthesia personnel are frequently not gowned and have their arms exposed. In addition, a majority of providers do not wear gloves for the entire procedure, which exposes their hands to blood from manipulation of intravascular catheters and contaminated equipment (Tait & Tuttle, 1995).

The contamination of the gloves, or hands, with sputum, blood, urine, spinal fluid or any other potentially infectious material can lead to the contamination of anesthesia equipment and monitoring equipment. In addition to tactile contamination, the possibility of blood aerosolization must also be considered. Aerosolization can occur by the oral route when patients cough, or by the surgical staff using mechanical devices, such

as lasers, drills, or other surgical devices which create a spray. Although sputum is not listed as a potentially infected body fluid by OSHA or CDC, the prevalence of blood in the sputum following intubation makes it a potentially infectious medium for the anesthetist (Chrisco & Devane, 1992; Philips and Monaghan, 1997). Chrisco and Devane reported as many as 72% of patients were positive for blood in the oropharynx after extubation. Following dental procedures, it was found that while HBV was not present in the air, it was present on environmental surfaces in the treatment room. This was credited with the weight of the aerosolized particles containing the virus pulling them out of the air, and onto the surfaces in the room (Ibrahim & Perceval, 1992).

Although no studies have been conducted to examine this phenomena in the operating room, the presence of aerosolization of blood leading to contamination of equipment is very likely. Equipment contaminated by hand or through aerosolization can become a reservoir for pathogens. As the working day continues, the bioload of pathogens may increase with each case, as will the potential for cross-infection. It is therefore important that anesthesia equipment be properly cleaned and disinfected in accordance with appropriate regulatory guidelines.

Purpose of the Study

The purpose of this study was to determine the prevalence of visible and/or occult blood on anesthesia equipment and monitoring equipment identified as ready for use. Anesthesia equipment tested included anesthesia machine vaporizer control dials,

ventilator control knobs, and flow meter control knobs. Monitoring equipment consisted of pulse oximeter probes, non invasive blood pressure cuffs, and electrocardiograph (EKG) monitor cables. The presence of blood would indicate that the equipment was not adequately cleaned or disinfected.

Research Questions

1. Is visible or occult blood present on anesthesia and patient monitoring equipment prior to the first surgical case of the day?
2. Are the surfaces of anesthesia and patient monitoring equipment being contaminated with blood during the operative procedure?
3. Is visible or occult blood present on anesthesia and monitoring equipment prior to the second surgical case of the day?

Conceptual Model and Framework

In 1859 Florence Nightingale published Notes on Nursing. She put forth the theory that it was of utmost importance to provide a clean environment for patients. Although she did not believe in the germ theory, she did offer the idea of asepsis as the means to control infection. This attitude which was considered radical among the health care providers of the day, was later espoused by the medical community. In the book, The Household Physician, published in 1926, Buffum and colleagues reiterated the admonition to maintain asepsis in the care of surgical patients while adding the emphasis

of the germ theory to the explanation (Buffum, Lovering, et. al, 1926). While they did not give credit to Nightingale, their discussion on the need for quiet, adequate fresh air, nutrition, and a clean environment could have been directly taken from her book.

This understanding that the provision of aseptic equipment and a clean environment is the cornerstone of basic patient care has been expanded on by governmental and other agencies. These regulatory agencies now recommend, or in some cases require, disinfection and sterilization procedures specific to the operating room and the specialties therein. These regulatory agencies include the Association of Operating Room Nurses, the Occupational Safety and Health Association, the Centers for Disease Control and Prevention, and the Joint Commission on Accreditation of Hospitals. So important are these principles, that finding of non-compliance can lead to fines, or lack of accreditation.

In the operating environment, today more than ever, the emphasis appears to be on the fast turnover of the operating suite. For three years I worked as the Infection Control Officer for a hospital and each month was faced with a number of surgical wound infections, as well as other nosocomial infections in surgical patients. No common factor could be found, with the exception that most of the patients showing up on my list every month were surgical patients.

At no other place in the hospital are patients more vulnerable than in the operating room. They have the integrity of their skin breached, their airway is entered and exposed for hours and they are unable to protect themselves from the risk of the environment by nature of their unconscious state. The anesthesia staff is given the responsibility to act as

an patient advocate and protect the patient from all environmental risk. However, in the haste to turn over the operating room little attention may be expended on the decontamination of anesthesia and monitoring equipment. This was the basis for the interest and importance of this study.

The American Practitioners of Infection Control (Rutula, 1996) and American Association of Nurse Anesthetists (AANA, 1993) infection control guidelines were followed to determine the type of cleaning and disinfection necessary for adequate preparation of the anesthetic equipment involved in this study. These guidelines are based on the definitions of E.H. Spaulding. Spaulding divided medical equipment into one of three groups. He designated these as critical, semicritical or noncritical items (Spaulding, 1972).

Critical items are those that may come in contact with sterile tissue or the vascular system. For these items sterility is of utmost importance. Many of the anesthetic supplies used for cannulation or intubation, (endotracheal tubes, suction devices), belong in this category and are usually purchased sterile and used on one patient only. The alternative to purchasing sterile items is to have them sterilized after each use.

Semicritical items are described as those which come in contact with mucous membranes or non-intact skin. These require that all micro-organisms be destroyed, with the exception of bacterial spores. Respiratory therapy equipment and laryngoscopes are in this category. These items require a high level disinfection utilizing either a wet pasteurization or disinfection with a chemical agent. Heat sterilization continues to be the preferred method for this category of equipment.

Noncritical items are those which come in contact with intact skin but do not contact mucous membranes. The equipment items identified for testing in this study were in this category. These items can be cleaned and disinfected at the site where they are used. Although the APIC guidelines state that there is little chance of infection related to these items, the argument can be made that at times, these items do come in contact with non-intact skin, or that pathogens residing on their surfaces can be introduced into these areas by the hands of health care personnel.

In addition, the 1992 OSHA standards and the 1993 AANA guidelines require immediate decontamination of all surfaces contaminated with blood or other potentially infectious materials. The possibility of patients having non-intact skin in contact with a contaminated and continuously re-cycling blood pressure cuff, or having blood present on the inner surface of pulse oximeter probes, allowing blood-borne pathogens to enter any break in the skin surface are not specifically discussed in the APIC guidelines. It is therefore important to use these as “guidelines” only, remembering mandatory adherence to the OSHA standards, and the continuous vigilance necessary to ensure patient and staff safety.

Definitions

The following are key words used in this study:

Sterilization

The complete elimination or destruction of all forms of microbial life. This can be accomplished by physical or chemical processes such as pressurized steam, ethylene oxide gas or the use of liquid chemicals (Rutala, 1996).

Disinfection

Eliminates many or all pathogenic microorganisms, except bacterial spores, from medical equipment. This is accomplished through the use of liquid chemicals, or wet pasteurization (Rutala, 1996).

High Level Disinfection

Used to destroy all microorganisms except for high numbers of bacterial spores (Rutula, 1996).

Intermediate level disinfection

Inactivates mycobacterium tuberculosis, most viruses and most fungi, as well as vegetative bacteria. It does not kill bacterial spores in all instances (Rutula, 1996).

Low level disinfection

Employed when it is important to kill most bacteria, some viruses and some fungi. It is not used with it is necessary to kill more resistant organisms or bacterial spores. It can not be relied upon to kill the tubercle bacilli (Rutula, 1996).

Germicide

A chemical which is used to destroy microorganisms (Rutula, 1996).

Disinfectant

A germicide which inactivates almost all pathogenic microorganisms on inanimate objects. It cannot be depended on to inactivate bacterial endospores (Rutula, 1996).

Nosocomial Infection

An infection that was not present or incubating at the time of admission to the health care facility, or at the time the patient presented to the health care provider for care.

Cleaning

The removal of all foreign material from objects. It is important to first clean an object prior to disinfection. Failure to do so may interfere with the disinfection process (Rutula, 1996).

Universal Precautions

An isolation method described by the CDC and adopted by most health care facilities. It is required by the Joint Commission on the Accreditation of Hospitals. Under this guideline all patients are to be considered potentially infected with HBV or HIV for purposes of staff and patient precautions (CDC, 1988).

Potentially Infectious Materials

A list of body fluids developed by OSHA and the CDC which must be included in Universal Precautions. These include: blood, tissues, semen, cerebrospinal fluid, amniotic fluid, synovial fluid, pericardial fluid, pleural fluid, amniotic fluid, vaginal secretions, milk from nursing mothers, and any other body fluid containing blood (CDC, 1987, 1988; OSHA, 1992).

Visible blood

Blood easily observed by the human eye.

Occult blood

Blood that can only be determined to be present thorough the use of microscopic examination or chemical testing.

Anesthesia Equipment

Anesthesia equipment is defined as the vaporizer control used to dial in the percent of volatile agents attached to the anesthesia machine, the ventilator controls knobs used to turn the ventilator on and control the rate and tidal volume, and the flow meter knobs, which are used to control the flow of the oxygen, nitrous oxide and air.

Monitoring Equipment

Monitoring equipment is defined as the EKG monitor cables used to attach the EKG electrodes to the patient, the inner and outer surface of the blood pressure cuff, and the inner and outer surface of the pulse oximeter probe.

Assumptions and Limitations

There are a few limitations to this study. The possibility of the “Hawthorne effect” exists. The “Hawthorne effect” is possible when the study group is aware of the study guidelines and this prior knowledge influences the behavior and alters the outcome of the study (Burns & Grove, 1993). For this study the chairman of each anesthesia department was informed of the study and the method which would be used to collect

data. The members of the department were not informed of the date of collection until the first samples had been obtained.

At the first institution, the days used to collect the samples were consecutive, and it was noted that the staff was attempting to disinfect the equipment more thoroughly on the second day. The analysis of the statistics showed a decrease in the percentage of positive samples of some pieces of equipment.

At the second institution, the department head was informed the day prior to data collection and the staff were not aware of the sampling until it was taking place. To offset the possibility of the “Hawthorne effect”, I did not return to collect the second sample group for a period of several weeks.

An assumption was made that the 70% isopropyl alcohol swab used to collect the sample prior to the first case, had in fact disinfected the equipment. This assumption was based on the ability of 70% alcohol to act as an environmental disinfectant and was the basis for the statement that the equipment was being contaminated during the second operative procedure of the day. Although care was taken to swab the equipment in the same area each time, it is possible that the equipment was in fact not completely disinfected the first time the sample was taken.

There was little possibility of contamination by the researcher during the sampling procedure, as disposable gloves were used and changed between samples. A sterile alcohol swab was opened, used immediately and placed in a separate bag for each sample.

Based on the sensitivity of the phenolphthalein test in previous studies (Philips & Monaghan, 1997 and Hall, 1994) the sensitivity of identifying blood at sixty seconds was determined to be 1:10,000 parts blood to normal saline. The tests were read at sixty seconds and those samples noted to have a pink color change were listed as positive. Some of the samples indicated a color change between sixty and 120 seconds. It is possible that there was a more dilute level of heme present on those samples, which would have increased the number of positive findings.

Testing for occult blood was limited to only indicating that the medical equipment had blood present on the surface. No effort was made to assess blood borne infectivity or the degree of actual contamination.

CHAPTER II: REVIEW OF THE LITERATURE

In 1988 Browne and Chernesky published an article on infectious diseases and the anaesthetist. They identified anesthetic equipment that should be subjected to varying levels of disinfection, and procedures to be used to prevent infections between patients and staff. Identification of body fluids to which the anaesthetist could be exposed were listed. Those pathogens identified as being present in blood included HBV, HIV, non A non B hepatitis, Cytomegalovirus, and Epstein-Barr virus. In summary, they recommended that the anesthetists adhere to universal precautions and employ adequate cleaning and disinfection of all patient care equipment to ensure each patient had a “fresh supply”.

In 1992 Chrisco and DeVane used a convenience sample of 163 patients undergoing oral endotracheal intubation for general anesthesia to test for the presence of overt or occult blood in the oropharynx. They demonstrated the presence of occult blood following intubation in 34% of the patients; following extubation the percentage was increased to 72%. The blood found in both instances was primarily occult. They concluded that this blood provided a potential means of transmitting HBV, HIV and other blood-borne diseases.

O'Donnell and Asbury researched the attitude of British anaesthetists toward the risk of exposure to HIV or HBV, and their compliance with the standards of the British Association of Anaesthetists. Their results were based on the responses to questionnaires obtained from 1,900 anaesthetists. They demonstrated that 81% of the

respondents recognized they were at risk for HIV, while only 69% perceived a risk from HBV. In addition, this study found that only 16% of the respondents wore gloves for placing intravascular lines or for endotracheal intubation. Among the 16%, 40% did not change gloves between patients. The overall conclusion of these researchers was that the recommendations regarding universal precautions were not being adhered to by the British anaesthetists (O'Donnell & Asbury, 1992,a).

A follow-up analysis of the same data set examined differences in perceptions and practices among anaesthetists based on age, time in practice, and region (O'Donnell & Asbury, 1992,b). The results indicated that anaesthesia residents were more likely to use gloves and perceive themselves at being at risk than were the anaesthetists who were in practice for a longer period of time. They also found less adherence to universal precautions and a lower rate of immunization for HBV among the older anaesthetists.

In 1993 Telford and Quebbeman conducted research to assess the risk of blood exposure in the operating room. They divided the body into 13 areas and examined these areas for blood contamination at the end of a surgical procedure. They found that the total number of contaminated areas averaged 0.56 per operation for procedures lasting less than 2 hours, but greater than 2.0 for those procedures lasting greater than 4 hours. They concluded that length of operative procedure played a part on the level of contamination of operating room staff. They also noted a decrease in hand contamination when operating room staff used two gloves on each hand. This allowed for the removal of a contaminated glove, while allowing protection from the remaining glove.

A similar study was conducted by Lynch and White in 1993 to examine blood contact during perioperative procedures. In this study they sampled nine hospitals and examined 8,502 surgical procedures. They found a total of 1,054 staff members exposed to blood during those procedures. These included 252 instances of blood splattering to the face or neck of the operating room staff. In examining the risk of exposure to blood based on job classification, they found anesthesia staff were bare-armed during procedures, which lead to cutaneous contacts with their upper extremities. In addition, they found that anesthesia personnel frequently manipulated the intravascular cannulas with un-gloved hands, which often resulted in contamination of the hands with blood.

In 1992, Martone, Jarvis, Culver and Haley authored a chapter for the 3rd edition of Hospital Infections, which examined the incidence and nature of nosocomial infections. Much of the pertinent information on nosocomial infections presented in Chapter One of this proposal were related to this source. In addition to those statistics already discussed, they identified nosocomial infections as perhaps the tenth leading cause of death in the United States. They concluded their chapter by stating that approximately one third of nosocomial infections could be prevented by the institution and maintenance of infection control programs.

In 1993 Short and Bell examined sero-prevalence among health care workers in the operating and delivery rooms. In this meta-analysis they examined the findings of other studies which had examined HBV and HIV seroprevalence. Their statistics on anesthesia staff were higher than either surgeons or the general population.

In the book, Understanding anesthesia equipment (1984), Dorsch and Dorsch delineates the type of cleaning and disinfection recommended for different types of anesthesia equipment. They state, “ The anesthesiologist should always work from a clean surface... All used articles should be placed in a special receptacle that is physically separated from the clean area” (p. 430). As to the proper cleaning of the instruments focused on in this study, he discusses the proper cleaning and disinfection procedures as follows:

The top, front and sides of the anesthesia cart should be wiped off with a detergent germicide once daily and a clean cover placed on the top at the start of each day. Blood or secretions should be wiped promptly. In addition, at least once a week...equipment should be removed and the drawers washed and then wiped with a germicide. (p. 433)

Dorsch continues with the admonition to treat the anesthesia machine in the same manner one would treat other operating room furniture. This includes wiping off horizontal surfaces between surgical cases and a thorough cleaning and disinfection daily, with special attention to knobs, vaporizers, and other attachments. He identifies blood pressure cuffs as reservoirs for potential infection and recommends cleaning procedures, which involve the removal of the rubber bladder, and soaking in detergent solution (p. 434).

In 1994, Hall conducted the only study which directly examined the presence of blood on anesthesia equipment other than laryngoscopes or laryngoscope handles. He identified 19 surfaces on anesthesia machines, anesthesia carts or patient monitoring

equipment. In that study he used 22 operating suites in two hospitals. His method involved the use of a three stage phenolphthalein blood indicator test to identify the presence of occult blood. He concluded that 33% of the surfaces he tested were contaminated with blood. Of those tested, he found 59% of the oximeter probes, 64% of the drawer handles, and 82% of the monitor cables were contaminated. Of interest was the finding that while 137 of the 418 surfaces tested were contaminated with blood, blood was only visible on three of the surfaces. He discussed his observation that the gloves of the anesthesia staff were contaminated during intravascular cannulation and endotracheal intubation and the possibility that this was the source of the equipment contamination. In addition to the recommendation of removing contaminated gloves, the author also called for redesign of anesthesia machines and the re-assigning of blood-pressure cuffs and oximeter probes to a higher level disinfection category.

In 1994 Tait and Tuttle designed a survey of anesthesiologists to determine practices undertaken to prevent transmission of infection. They sampled 4% of practicing anesthesiologists in the United States and questioned them regarding their compliance to the 1992 CDC universal precaution guidelines and their adherence to recommended procedures designed to prevent transmission of infections to their patients. Of the 1,149 surveys mailed, 493 anesthesiologists, (43%), responded.

From the data collected for this survey, they presented that 93% of the sample reported that they washed their hands if the patient was known to be infected with HIV or HBV, while only 58% reported washing their hands after contact with patients not identified as high risk. Only 12 % admitted to always disinfecting anesthesia work

surfaces, while 60 % responded that they rarely or never disinfected these surfaces. The researchers also discuss the increasing number of immuno-compromised patients to whom anesthesia is being delivered and the increased risk of mortality in this group.

In 1990 Gadalla and Fong, in a letter to the editor of *Anesthesiology* , discussed the observation that the actions of anesthesia personnel could lead to cross contamination between patient and provider. According to the communication, after the induction of anesthesia the providers often place the dirty laryngoscope on the same surface that was holding the syringes, tubes, airways and other anesthetic equipment. This surface, now contaminated, may serve to contaminate the clean equipment to be used for this patient and subsequent patients. They recommended a “clean method of performing induction that employed a double glove technique. Although this was recommended seven years ago, and would offer protection to the clean surface of the anesthesia table, it is not commonly employed by anesthesia providers.

The new APIC guidelines for use of disinfectants were published in 1996 (Rutula, 1996). In this standard providers are cautioned against using a double standard when disinfecting equipment. This means that to use one standard when the patient is known to have HIV or HBV, and another when the status is unknown, places the provider at increased liability for standard of care violations. In addition, the fact that HIV and HBV status usually is not determined at the time of surgery, places the provider and the patients at increased risk if the most stringent policies are not followed.

In 1996 Phillips and Monaghan used a modified phenolphthalein blood indicator test to demonstrate the presence of occult blood on laryngoscope blades and handles.

Blades and handles were tested prior to the first case of the day and at varying times thereafter. This study revealed that the later in the day the blades were tested, the greater the percentage of blades found positive for blood. She discussed the possibility that the handle, contaminated during the first intubation of the day, served to cross-contaminate the blades used for all following intubations. Philip's study indicates that blood is a by-product of intubation that may serve to contaminate gloves, hands, anesthesia equipment, monitoring equipment, patients and medical staff (Philips & Monaghan, 1997)

Summary

Several studies have demonstrated the lack of compliance on the part of anesthesia providers with existing standards of cleaning and adherence to universal precautions. However, only one study was found which tested for the presence of occult blood on anesthesia equipment other than laryngoscope blades and handles (Hall, 1994). This study called for the redesign of anesthesia equipment to allow for easier disinfection and for the re-assessment of the level of disinfection required for some patient monitoring equipment. Clearly more research is needed to demonstrate the importance of this problem.

CHAPTER III: METHODS

Research Design and Procedures

Data for this descriptive study was collected from two hospitals in the state of Maryland. One is a military hospital with five to seven operating rooms, and the other is a civilian facility with approximately 12 operating rooms. Twenty eight operating suites were used for this study. This was the number of rooms having operative procedures on the days selected for data collection. These 28 rooms allowed for 57 samples of each piece of study equipment. Several rooms had cases canceled, which allowed only one sample group from that room.

Prior to the first case of the day, a visual inspection was made of the identified equipment in each operative suite to determine if any blood was visible on the test equipment. Each piece of equipment was sampled by wiping the surface with a 70% isopropyl alcohol swab. Each swab was then placed into a plastic zip lock type bag labeled with the equipment type, the operating room from which it was obtained, the facility where it was obtained, and the study group it represented.

Two days were used for data collection at each facility. On the first day at each facility, the equipment was re-inspected for visible blood and tested again for occult blood at the immediate conclusion of the first operative procedure. On the second day of data collection, the equipment was re-inspected and tested immediately prior to the beginning of the second case. (See Figure 1).

Measurement

Swabs from the samples were tested for occult blood using a three-stage phenolphthalein blood indicator test. The results were recorded as to the presence of visible blood on the equipment, the presence of occult blood on the equipment, or the lack thereof. If a piece of equipment was positive for visible blood, the visible stain was tested using the phenolphthalein test to verify that the stain was blood.

The phenolphthalein test was performed utilizing the Phenolphthalein Test Kit, Cluefinders, Inc. This chemical analysis works on the principle of an oxidation-reduction reaction. When a sample containing heme is present, the phenolphthalein reagent dropped onto the sample is oxidized due to peroxidase activity. When hydrogen peroxide is then added, it is broken down, the oxygen is transferred to the phenolphthalein reagent, thereby oxidizing the phenolphthalein and resulting in a pink color change. (Phenolphthalein Test Kit, Cluefinders, Inc., Tampa Florida).

The instructions provided by the manufacturer described using filter paper to wipe the surface, and then adding one drop of 70% isopropyl alcohol. In 1996, Phillips compared the results of collecting the samples on 70% isopropyl alcohol swabs with those of collecting the samples on filter paper and adding a drop of 70% isopropyl alcohol. She concluded that “ the modification did not change the validity of the phenolphthalein blood indicator test” (Phillips & Monaghan, 1997, p. 243). Her results showed the sensitivity of the modified three stage phenolphthalein blood indicator test to

be 1:10,000 at sixty seconds. The modified method used by Phillips was used for this research.

After collection each sample was tested by placing one drop of phenolphthalein reagent on the alcohol swab samples. If a pink color was observed this test would have been ruled invalid. This did not occur on any of the samples tested for this study. If no color change was noted on the sample swab, one drop of hydrogen peroxide was placed on the swabs. If a pink color was observed at this time, the test was ruled positive for heme. A known bloodstain control card, supplied by the “Cluefinders” kit manufacturer was used to verify the solutions’ reliability. It reacted positively when tested with a sample of the researcher’s blood. The reagents were also tested by exposing them to clean alcohol wipes to rule out false positive reactions. It was noted that after placing the reagents on clean 70% alcohol swabs, a pink color could be faintly observed at the end of approximately 2 minutes. For this reason the swabs were read for color change within 60 seconds of placing the reagents. Any color change occurring after this time was disregarded.

Protection of Human Rights

Each institutional review board was contacted and it was determined that no consent was required since no human or animal subjects were used in this study.

Data Analysis

All results were recorded as positive or negative for visible or occult blood on a data collection tool (See appendix). The collected data were analyzed and percentages were computed based on the number of positive results. The standard error of a proportion of rates of occurrences were calculated to determine the significance ($p < .01$).

CHAPTER IV: ANALYSIS

Results

A total of 342 observations of six different pieces of equipment were made. This included 174 observations taken prior to the first case of the day, 78 taken immediately following the first case of the day, and 90 taken immediately prior to the second case of the day. Of these observations, a total of 110 were positive for blood when tested with the phenolphthalein blood indicator test. This was calculated to represent a 32.1% positive finding for the total observations.

Prior to the first case of the day 36.7 % of all sampled equipment were found to be positive for occult blood and one specimen, an EKG cable, was positive for visible blood. Immediately after the first case of the day, occult blood was present on 35% of the observations. Visible blood was found on two pieces of equipment in this group. Immediately prior to the second case of the day, occult blood was present in 31% of the observations, with only three positive for visible blood. These results are broken down by facility and equipment type in Tables 1-3 and Figures 1-2.

Analysis by facility showed that 27% of 210 observations from the facility number one were positive compared with 41 % of 132 observations from facility number two. All equipment displaying visible blood were found in facility two. The data sheets were reviewed to see if the same piece of equipment was positive after the case as before. Although wiping the surface of the equipment with the alcohol swab should have cleaned

the equipment, it is possible that some heme was left behind. If this were the case the sample results could be skewed as the same piece would be counted twice. Analysis showed that 50% of the equipment testing positive for heme during the second sampling time was negative when tested prior to the first surgical case. This supports the second and third statements below.

Therefore:

1. Visible and/or occult blood was present on anesthesia and patient monitoring equipment prior to the first surgical case of the day.
2. Surfaces of anesthesia and patient monitoring equipment were contaminated with blood during the operative procedure.
3. Visible and/or occult blood was present on anesthesia on monitoring equipment prior to the second surgical case of the day.

Table 1.

Prevalence of Blood on Anesthesia Equipment and Monitoring Equipment

Facility #1

| Equipment Percent Surfaces | Sample Totals | Number of Observations | | |
|----------------------------------|------------------|------------------------|--------------------|--------------------|
| | | Visible Blood | Occult Positive | Occult Positive |
| Ventilator controls | 35 | 0 | 8 | 23 |
| Flow meter knobs | 35 | 0 | 14 | 40 |
| Vaporizer controls | 35 | 0 | 7 | 20 |
| EKG monitor cables | 35 | 0 | 19 | 54 |

| | | | | |
|------------------------------|------------------|-----------------|-----------------|-----------------|
| Pulse oximeter probes | 35 | 0 | 6 | 17 |
| Blood pressure cuffs | <u>35</u> | <u>0</u> | <u>3</u> | <u>6</u> |
| Total | 210 | 0 | 57 | 27% |

Table 2.**Prevalence of Blood on Anesthesia Equipment and Monitoring Equipment****Facility #2**

| Equipment Surfaces | Number of Observations | | | |
|-----------------------|------------------------|---------------|-----------------|------------------|
| | Sample Totals | Visible Blood | Occult Positive | Percent Positive |
| Ventilator controls | 22 | 0 | 6 | 27 |
| Flow meter knobs | 22 | 0 | 5 | 22 |
| Vaporizer controls | 22 | 0 | 8 | 36 |
| EKG monitor cables | 22 | 4 | 14 | 82 |
| Pulse oximeter probes | 22 | 1 | 4 | 23 |
| Blood pressure cuffs | 22 | 1 | 11 | 55 |
| Totals | 132 | 6 | 48 | 41% |

Table 3.**Prevalence of Blood on Anesthesia Equipment and Monitoring Equipment, Both****Facilities and by Machine Type**

| Equipment Surfaces | Total # of Observations | Percent Positive | Anesthesia Machine Type | | | |
|-----------------------|-------------------------|------------------|-------------------------|----|-----|----|
| | | | Percent Positive | | | |
| Ventilator controls | 57 | 24 | (O) | 23 | (N) | 27 |
| Flow meter knobs | 57 | 33 | (O) | 40 | (N) | 22 |
| Vaporizer controls | 57 | 26 | (O) | 20 | (N) | 36 |
| EKG monitor cables | 57 | 65 | N/A | | N/A | |
| Pulse oximeter probes | 57 | 17 | N/A | | N/A | |
| Blood pressure cuffs | 57 | 26 | N/A | | N/A | |

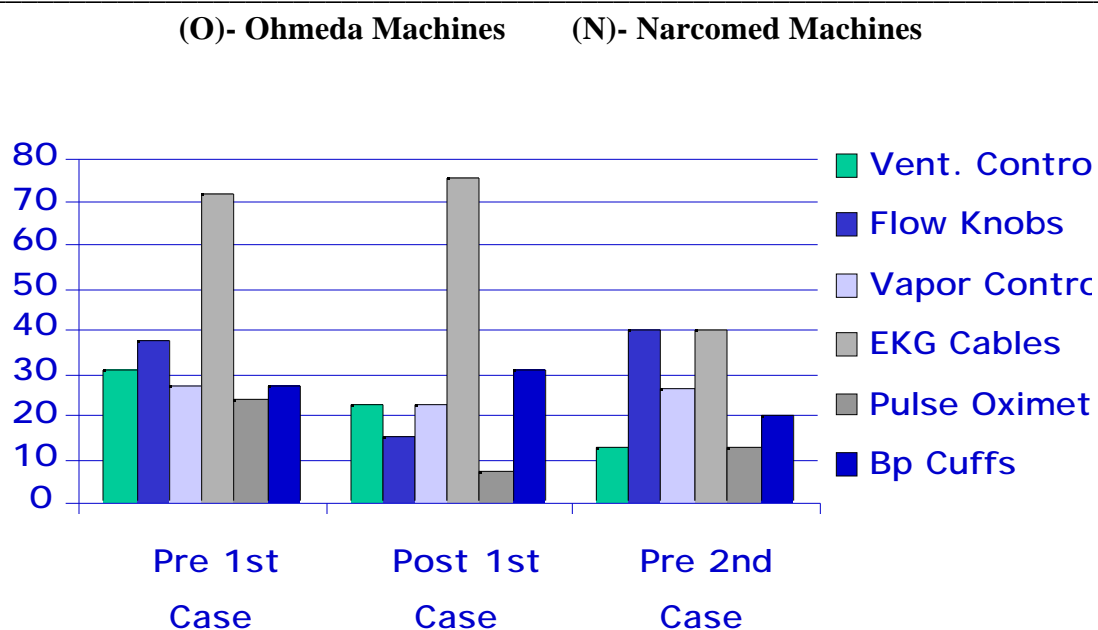


Figure 1.

Percentage Positive for Heme by Sampling Time, Both Facilities Combined

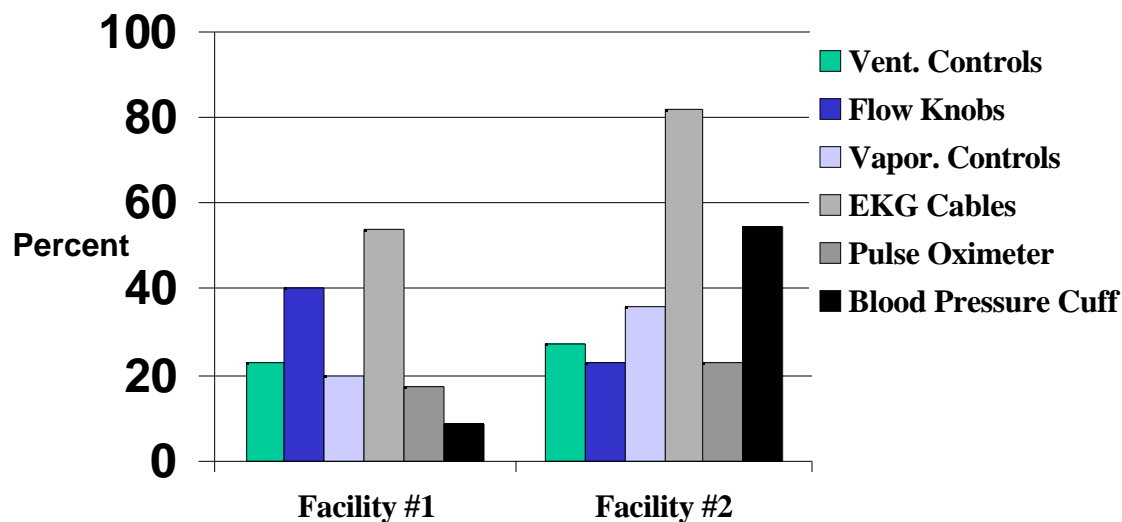


Figure 2.

Percentage of Equipment Positive for Heme by Facility

CHAPTER V: SUMMARY

Conclusions and Recommendations

Thirty-seven percent of all surfaces tested were positive for blood contamination. The results were conclusive that anesthesia and monitoring equipment are being contaminated with blood and they are not being adequately disinfected before use on another patient.

There were differences between the percentage of equipment surfaces positive for each facility. Neither facility had written guidelines for specifically cleaning or disinfecting this equipment between cases. When questioned about the cleaning practices, the staff at both facilities indicated that they cleaned the equipment if they could see it was contaminated with blood. Responsibility for the cleaning task was different at each facility. At the first facility, the operating room nurses and technicians were responsible for cleaning the room. At the second facility the cleaning was shared between the housekeeping and anesthesia technicians.

In addition to the occult blood that was found during the testing, the alcohol swabs also picked up dust and dirt from the majority of the equipment tested prior to the first case of the day. This indicates that the equipment had not been cleaned sufficiently enough to remove even surface dust

Visibly inspecting the equipment for blood is not a reliable means for determining which equipment require decontamination. In this study, only six of the 342 samples

were positive for visible blood. The dark surfaces of the anesthesia ventilator and vaporizer controls, the blood pressure cuff surfaces, and the pulse oximeter probes make the presence of blood difficult to observe with the naked eye. The EKG cables have a red, black, and sometimes a brown lead, which also make the identification of blood difficult to view with the naked eye. In addition, the length and cable design make it difficult to examine them carefully between cases. The surfaces of the equipment are not designed for easy cleaning. The knobs on the anesthesia machine are knurled or grooved and some are black in color. The facilities used different brands of anesthesia machines and the differences in the findings are listed in Table 3. The largest difference was noted with the vaporizer controls on the machines at facility 2, which were found to be positive for blood in 36% of the observations. The machines at facility number 1, were positive in 20% of the observations. These differences may be the pursued in future studies. At the time of this study there was no obvious reason for the difference.

The results of this study are similar to those found by Hall (1994) who looked at the “Blood Contamination of Anesthesia Equipment and Monitoring Equipment” (p.1136). His study included nineteen equipment surfaces related to anesthesia and monitoring equipment. Using the phenolphthalein blood indicator test, he found 33% of the surfaces positive for blood. This study replicated portions of his study, and supported those findings. In his research he discussed the “inability to effectively decontaminate the anesthesia machine, including work surfaces and knobs (p. 1138).”

This study revealed that the anesthesia staff, and others responsible for decontaminating this equipment at each facility, may not have been in compliance with

OSHA or AANA guidelines. These guidelines state that all surfaces contaminated with blood or other potentially infectious materials must be cleaned, and then decontaminated with sodium hypochlorite solution immediately after contamination (AANA, 1993 & OSHA, 1991). In addition, the Standards for Nurse Anesthesia Practice (1989) adopted in 1990 state, “The CRNA shall check the readiness, availability, cleanliness and working condition of all equipment to be utilized in the administration of the anesthesia care (1989, p. 5).” This statement clearly places the responsibility for ensuring clean and disinfected equipment on the nurse anesthetist providing anesthesia for the operative procedure. At neither facility did the nurse anesthetist or anesthesiologist have a designated responsibility to clean the machine or equipment.

Facility 1 was a civilian facility and the operating room nurses were tasked with cleaning the operating room and equipment. Facility 2 was a military facility and enlisted personnel and housekeeping staff were responsible for cleaning. A higher percent of contamination was observed at the military facility (27% versus 41%). This variance could represent a difference in level of education and training and is an area for further investigation.

Although it is beyond the scope of this study to demonstrate the risk for infection from the blood found to be present on the equipment, the potential for acquiring a blood-borne pathogen infection is increased by the mere presence of blood. OSHA standards requiring cleaning and disinfection of equipment contaminated with blood, and the requirement to use universal precautions are designed to protect the staff and patients

from blood. The foundation for these requirements is that any blood may be potentially infectious.

The surfaces of the anesthesia machine were most probably contaminated by the hands or gloves of anesthesia personnel. By observing the practices of the anesthesia staff it is easy to track the probable mode of contamination. Immediately after intubation, still wearing the gloves used for the intubation, (and sometimes, the same gloves used to start an intravenous line), the anesthesia provider frequently turns on the ventilator and adjusts the flow meter and vaporizer dials. Taking off the gloves at a later time, the anesthetist then touches those same dials throughout the surgery, increasing the risk of contracting a blood-borne disease.

To avoid this contamination, and reduce the risk to the provider and subsequent patients, the anesthesia provider should either remove the gloves immediately after intubation, or use a double glove technique during intubation. This technique requires that the anesthetist don two pairs of gloves. After intubation one pair of gloves would be removed prior to adjusting the anesthesia machine dials. The second pair of gloves allows the provider continued protection. This second choice is probably the safest, as the equipment may not have been decontaminated from the prior case. Also the sequence of induction requires that the anesthesia provider's hand be close to the patient's mouth during placement of gastric tubes, airways, and esophageal stethoscopes. All these procedures will require gloves.

OSHA standards and the infection control policies of medical facilities require that hands should be washed immediately after removing gloves, or as soon as possible

thereafter (OSHA, 1991). However in the actual operating room there is no means for washing hands after removing gloves. This results in hands contaminated with blood or other infectious materials continuing to serve as a means to contaminate all surfaces they contact. This includes charts, intravenous lines, suction catheters, etc. This could be improved somewhat by the placement of a foam cleanser, or hand towellettes with a disinfectant at each anesthesia station.

The surfaces of the anesthesia equipment should be redesigned to allow for easy identification of the presence of blood and for reliable disinfection. This would mean using a lighter color on knobs and dials and altering the surface to do away with knurls and indentations. The current design of the machines is such that cleaning cannot be ensured even if an attempt is made to disinfect the machine surfaces. It should be noted that at no time during my observation did I note anyone providing more than a cursory wipe across the surface of the anesthesia machine. To remove blood from the gnarled surfaces and indentations would require a specific wiping technique and a considerable amount of time.

Blood pressure cuffs should be disposable or changed and disinfected between each case. The outer surface of the cuff was where the majority of the occult blood was noted, again pointing to the hands of the staff as the probable means of contamination. This surface may also be contaminated with blood during the procedure if the surgical site is proximal to the cuff location.

The EKG cables had the highest percentage of positive results, both in this study and that reported by Hall in 1994. The EKG cables are frequently dropped on the

operating room floor after the procedure and the operating room floor may be contaminated with blood. In addition, the operative site on many patients allows for blood to drip down onto the cables. The cables are also handled by the anesthesia and surgical staff during placement and disconnection. EKG leads and cables should ideally be disposable and changed between patients. The other alternative would be to design these to withstand a high level disinfection technique and require that they be disinfected between patient use.

Pulse oximeter probes are also easily contaminated with blood. They are frequently moved to various sites by the anesthesia or surgical staff and may be contaminated by hands or gloves. Usually placed on the patient's hand, they are easily contaminated by blood from intravenous or arterial punctures. Disposable pulse oximeter probes are available, but are currently being re-used by many facilities in an effort to decrease cost. It may be that facilities should use disposable pulse oximeters, or have them disinfected between cases by the central sterile supply staff, to ensure more than a cursory cleaning.

Each anesthesia department is required to prepare and maintain an infection control policy for their department (AANA, 1989). It is also a part of the 1991 OSHA requirements. These should include specific instructions for cleaning anesthesia and monitoring equipment between cases and at the end of each day. A specific anesthesia team member should be tasked with this duty and quality control performed by the anesthesia staff to ensure compliance. This task should be performed by someone with

the education and training to understand the importance of the task and the proper method necessary to clean and disinfect this equipment.

The argument against these recommendations will no doubt be the additional cost of purchasing appropriate disposable equipment. In addition there would be considerable cost to redesign and purchase new equipment and machines. An additional argument may be the few extra minutes required between cases to ensure cleaning and disinfection of equipment. Although not demonstrated in this study, the cost of this research, as well as the re-design of and additional supply of equipment may be recouped by the decreased number of nosocomial and occupational infections. The risk to patient's and staff could be decreased dramatically by adequately disinfecting the equipment. If blood is removed from the environment there cannot be a risk of exposure. Two studies have now shown the prevalence of occult blood on equipment used by the anesthesia staff to be from 27% to 41%. It should be clear that the risk for exposure to blood borne pathogens may be increased for the staff and patients who have contact with this equipment.

In several studies anesthetists have demonstrated a lack of compliance with OSHA and infection control guidelines, although they have a higher risk for contracting a blood-borne occupational related infection (O'Donnell & Asbury, 1992, Tait & Tuttle, 1995, Short and Bell, 1993). Infection control education should be designed to do more than present a generalized view of the problem. A specific program should be developed for anesthesia staff specifically designed for the learning style and values of these practitioners. The general attitude of these practitioner's toward infection control must be modified before we can begin to see a real improvement in compliance with standards.

From the time of Florence Nightingale nurses have been aware of the importance a clean environment played in the health of patients. The responsibility of nurses to ensure an environment conducive to health has been the thread running through the profession since the 19th century. In addition, the nurse anesthesia professional knows that vigilance is paramount to safe patient care. This vigilance should include protecting them from blood-borne pathogens and decreasing their risk of nosocomial infections. As nurse anesthetist we must combine both of these responsibilities. We are negligent when we do not provide each patient with a clean environment and equipment as free from blood and potential pathogens as possible.

REFERENCES

- American Association of Nurse Anesthetists. (1989). AANA develops infection control guidelines for anesthesia. Journal of the American Association of Nurse Anesthetists, 57, (4), 299-302.
- American Association of Nurse Anesthetists. (1993). Infection control guidelines., American Association of Nurse Anesthetists, Oak Park, Illinois.
- Association of Operating Room Nurses. (1994). Proposed recommended practices for sterilization in the practice setting. Association of Operating Room Nurses Journal, 60, (1), 109-119.
- Bready, L. L. (1988). Infectious disease and anesthesia. Advances in Anesthesia, 5, 89-128.
- Browne, R. A., & Chernesky, M. A. (1988). Infectious diseases and the anaesthetist. Canadian Journal of Anaesthesiology, 35, (6), 655-665.
- Buffum, H. E. Warren I., Lovering, A. T., Small, A. E., Thorndike, W., Smith, J. H., & Lyman, C. P. (1926). The household physician: A twentieth century medica. Buffalo: Brown-Flynn
- Burns, N., & Grove, S.K. (1993). The practice of nursing research: conduct, critique, & utilization (2nd ed.). Philadelphia: W.B. Saunders Company.
- Centers for Disease Control. (1987, August 21). Recommendations for prevention of HIV transmission in health-care settings. Morbidity and Mortality Weekly Report, 36, (Suppl.2), 3S-18S.

Centers for Disease Control. (1988, June 24) Update: Universal precautions for prevention of transmission of human immunodeficiency virus, hepatitis B virus, and other blood-borne pathogens in health-care settings. Morbidity and Mortality Weekly Report, 37, (24) 377-382, 387-388.

Centers for Disease Control. (1992, October 23). Public health focus: Surveillance, prevention and control of Nosocomial infections. Morbidity and Mortality Weekly Report, 41, (42), 783-787.

Chrisco, J. A. & DeVane, G. (1992) A descriptive study of blood in the mouth following routine oral endotracheal intubation. Journal of the American Association of Nurse Anesthetists, 60, (4), 379- 383.

Crow, S. (1993). Sterilization process: Meeting the demands of today's health care technology. Nursing Clinics of North America, 28, (3), 687-695.

Dorsch, J. A., & Dorsch, S. E. (1984). Understanding Anesthesia Equipment: Construction, Care , and Complications (2nd ed.). (pp. 430-438). Baltimore, MD: Williams & Wilkins.

Gadalla, F. & Fong, J. (1990). Improved infection control in the operating room. Anesthesiology, 73, (6), 1295.

Haley, R. W., Culver, D. H., White, J. W., Morgan, W. M., Emori, T. G., Munn, V.P., & Hooton, T. M. (1985). The efficacy of infection surveillance and control programs in preventing nosocomial infections in US hospitals. American Journal of Epidemiology, 121, (2), 182-205.

Hall, J. R. (1994). Blood contamination of anesthesia equipment and monitoring equipment. Anesthesia and Analgesia, 78, 1136-1139.

Ibrahim, J. J., & Perceval, A. K. (1992). Contamination of anaesthetic tubing-a real hazard? Anaesthesia Intensive Care, 20, (3), 317-321.

Kanefield, J. K., Munro, J. T., & Eisele, J. H. (1989). Are intubations bloody? Anesthesia and Analgesia, 68, S142.

Lynch, P., & White, M. C. (1993). Perioperative blood contact and exposures: A comparison of incident reports and focused studies. American Journal of Infection Control 21, (6), 357-363.

Martone, W. J., Jarvis, W. R., Culver, D. H., & Haley, R. W. (1992). Incidence and nature of endemic and epidemic nosocomial infections. In J. V Bennet & P. S Brachman (Eds.), Hospital Infections. (pp 577-596). Boston, MA: Little, Brown, & Company.

Nightingale, F. (1859). Notes on Nursing: What it is and What it is Not. London: Harrison and Sons.

O'Donnell N. G., & Asbury, A. J. (1992a). Perceived risks and preventive measures adopted by anaesthetists: a postal survey. Anaesthesia, 47, 923-928.

O'Donnell N. G., & Asbury, A. J. (1992b). The occupational hazard of human immunodeficiency virus and hepatitis B virus infection. Anaesthesia, 47, 929-935.

Occupational Safety and Healthy Association (1991). Occupational Exposure to Bloodborne Pathogens. Federal Register; 56:235, 64004-64182.

Phillips, R.A., & Monaghan W. P. (1997). The incidence of visible and occult blood on laryngoscope blades and handles. American Association of Nurse Anesthetists Journal 65, (3), 241-246.

Rosenquist, R. W., & Stock, M. C. (1989). Decontaminating anesthesia and respiratory therapy equipment. In J. L. Benumof & A. J. Berry (Eds.), Anesthesiology Clinics of North America, 7, (4), PP. 951-966). Philadelphia, PA: W. B. Saunders.

Rutala, W. A. (1996). APIC guideline for selection and use of disinfectants. American Journal of Infection Control, 24 (4) 313-342.

Short, L. J. & Bell, D. A. (1993). Seroprevalance for HIV and HBV in operating and delivery room settings. American Journal of Infection Control 21, (6). 343-350.

Spaulding EH. (1972). Chemical disinfection and antisepsis in the hospital. Journal of Hospital Research 9, 5.

Telford G. L., & Quebbeman, E. Q. (1993). Assessing the risk of blood exposure in the operating room. American Journal of Infection Control 21, (6), 351-356.

Tait A. R. & Tuttle, D. B. (1995). Preventing perioperative transmission of infection: A survey of anesthesiology practice. Anesthesia and Analgesia, 80, 764-769.